Coastal Engineering Technical Note

NATIVE BEACH ASSESSMENT TECHNIQUES FOR BEACH FILL DESIGN

PURPOSE: In order to properly design a beach nourishment project, the condition of the existing native beach needs to be determined. Characterization of the sediment grain size distribution and active beach profile envelope is needed to properly define volume of fill material required, the design profile template, and suitability of grain size distribution of the borrow material.

BACKGROUND: The native beach is a dynamic morphologic feature that will vary its form and sediment composition in the short term, both temporally and spatially. Variations on the temporal scale range from short term tidal cycle changes, through wave induced changes, to storm induced changes, to seasonal variations, to longer term sea level fluctuations. Spatial variations also may be present due to variations in geology of the area, transient morphology (such as beach cusps and bar features) and influences of shore protection structures (such as groins). In order to properly characterize a native beach, all of these time and space variations need to be considered. Ideally, profile surveys with concurrent sediment samples should be collected monthly throughout the year to define the seasonal and superimposed storm changes that occur. This amount of sampling is usually cost prohibitive and it is recommended (SPM, 1984) that a representative survey and sampling be done during the winter and summer. This frequency provides a minimum amount of information to characterize the range of active profile changes and grain size distributions expected as a result of seasonal variations. Impacts due to short term extreme events or tidal cycles are not captured, but the winter profile should characterize a general erosional type, coarse grained storm profile, while the summer profile will characterize an accretional type, finer grain fair weather profile.

Characterization of the native beach can be divided into two interrelated tasks, collection and analysis of the native beach grain size distribution and the beach profile. Several recent studies will be used to illustrate the utility of data collection and analysis in depiction of the native beach and its use in beach nourishment planning. An 18-month profile and sediment collection program was conducted at the CERC Field Research Facility (FRF) which detailed the monthly changes of a natural beach and provided insight to the storm and seasonal beach cycle (Stauble, in press a). Assessments of native beach characteristics at several recent beach nourishment projects also has been reported by Stauble, Hansen and Blake, 1984, Stauble and Hoel, 1986, Hansen and Scheffner, 1990 and Anders and Hansen, 1990.

SEDIMENT DATA: Beaches are made up of a variety of mineral components and contain a wide range of grain sizes that vary in both the cross-shore and long-shore directions. While the main component of most beach sediment is well rounded quartz sand, many beaches may contain from a few percent to almost 100 percent of such components as carbonate material (ie. shell, aragonite), rock fragments, and heavy minerals. The grain size distribution at any given point on the beach is a function of the depositional energy of the cumulative coastal processes (ie. wind, waves and currents). Usually the coarsest material, with the poorest sorting, is found at the shore break plunge point just seaward of the backrush, an area of high turbulence (Bascom, 1959, Stauble, in press a). A secondary coarse sediment distribution can be found on the top of the summer berm. Finer, better sorted material can be found in the dunes and also becomes finer as one moves seaward of the breakers. Figure 1 shows a grain size

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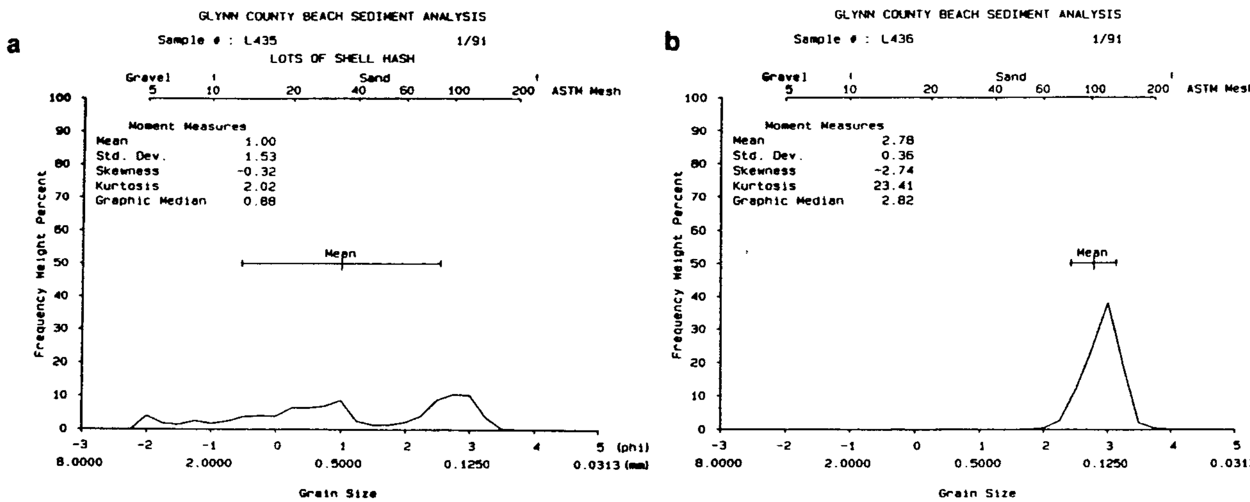

Figure 1. Spatial variation in grain size distributions across a profile at a) the high energy low tide/plunge point and b) -3 foot offshore sample on a naive profile at Jekyll Island, GA.

distribution curve of a coarse, poorly-shorted sample from the low tide plunge point, compared with a well sorted, fine grained sample from the - 3 ft. offshore area on Jekyll Island GA.

Field Sampling: Because of natural variability in grain size distributions, a sampling scheme needs to be developed to adequately sample the native beach in both the cross-shore and along-shore directions. Sediment samples need to be collected at the same time as the profiles are surveyed. That way, the samples can be spatially located and related to morphology and hydrodynamic zones. Generally, beach profile and sediment sampling locations are chosen with a regular alongshore spacing that adequately covers the limits of fill placement, including control profiles spaced 1 mile north and south of project limits. The actual number of profiles depends on cost and shoreline variability. For example, a beach with groins and pocket beaches will require more profile lines than a straight unobstructed shoreline. A suggested rule of thumb is every half mile, but engineering judgment is required to define adequate project coverage.

In the past, cross-shore sediment sampling often has employed samples taken at specific elevations (ie, +6, +3, 0, -3, -6 ft, etc...). It is suggested that samples be collected at morphodynamic zones on the profile (Stauble and Hoel, 1986), such as dune base, mid-berm, mean high water, mid-tide, mean low water, trough, and bar crest, and then at even increments to depth of closure. By sampling at specific morphologic locations, sediment grain size distributions can be directly comparable with subsequent surveys. Figure 2 illustrates results from this type of sampling for a winter and summer profile at the FRF. The coarse, more poorly sorted samples were found on the foreshore and trough area on the erosional winter barred profile. During the summer accretional berm profile, cross-shore grain size distributions are less varied but coarse, more poorly sorted samples were still found on the foreshore. Finer, well-sorted samples were found in the nearshore area and were uniform both times.

With no established guidance on determining location and number of samples to collect, Anders, Underwood and Kimball (1987) statistically determined the number of samples necessary to accurately characterize the beach, based on data collected at Ocean City, MD. They divided the beach into cross-

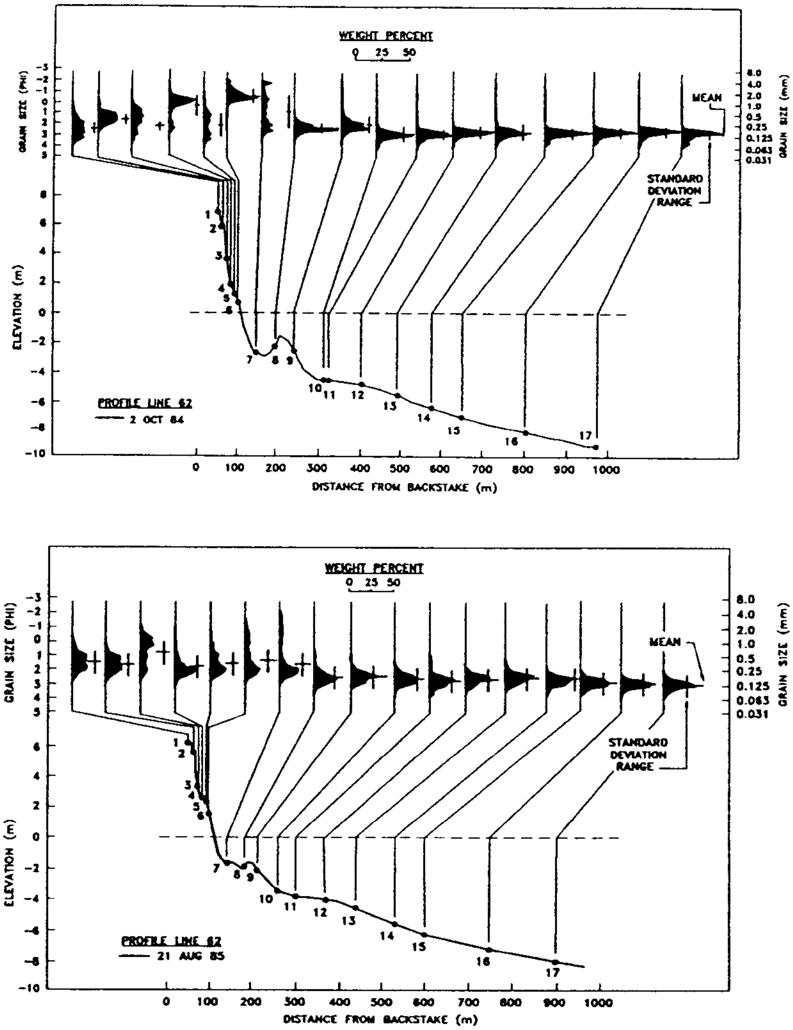

Figure 2. Grain size distribution across a) winter erosional bar profile and b) summer accretional berm profile showing seasonal grain size spatial variability. Note nearshore sample uniformity in both plots. (After Stauble, in press a)

shore sub-environments and found that coarser beach sub-environments (ie. plunge point) and beaches with coarse sand, in general, require more samples to accurately characterize the native sediment. Figure 3 provides some general guidance on the number of samples needed per sub-environment (for more details see Anders, Underwood and Kimball, 1987, or Anders and Hansen, 1990). For characterization of the native beach for beach nourishment purposes, it is suggested (Stauble and Hoel, 1986) that, at a minimum, samples be collected at the mean high water (MHW) line area (identified on most beaches by the maximum runup swash mark line), mid-tide (MT) area (half way between the MHW and MLW samples), and mean low water (MLW) area (at the plunge point where the backwash meats the incoming surf bore taken at time of low tide). These three locations provide a characterization of the foreshore beach where the fill will be placed and resorted by wave action. If possible, samples on the berm, in the trough and in the vicinity of the bar should be added, as these locations also are active depositional/erosional areas of fill material. The dune area (where wind blown sediment is deposited), and the offshore area seaward of the bar (or bars on profiles that have multiple bar systems, where the

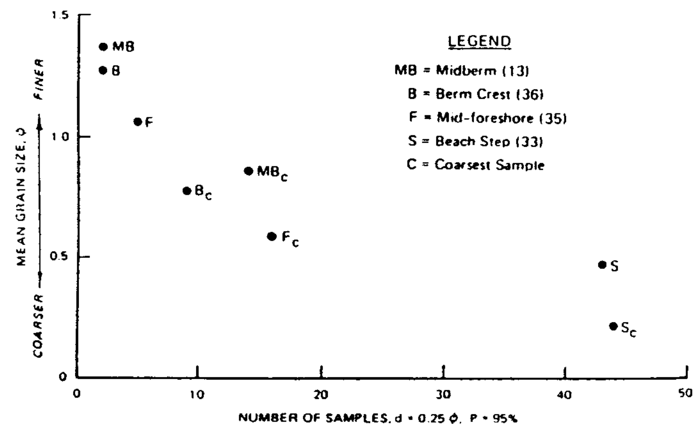

Figure 3. Plot of samples required in each beach sub-environment, based on mean grain size at Ocean City, MD (Anders, Underwood and Kimball, 1987).

sediment becomes uniformly fine-grained and well-sorted), are of lesser importance when trying to characterize the native beach for use in assessing borrow sediment suitability.

Sample collection consists of surface grab sampling of around 100 g (3.53 oz) of the shallow (less than 1 ft) depth on the subaerial beach. Offshore sample collection can be done with divers or grab samplers (ie. Ponar, Ekman clamshell, Smith-MacIntire). If timing does not permit collection of both a pre-project summer and winter sampling, a method described in detail in Anders and Hansen (1990) for collection of shallow (less than 6 ft.) cores can be used. The core will penetrate several layers of past depositional sequences within the active beach prism. Coarse layers can be related to lag deposits of high energy events while finer layers can be associated with fair weather deposition. This envelope of sediment will represent several layers of past deposition events and can be used to depict temporal changes.

Analysis: The following procedures are recommended for sediment grain size analysis:

1) Air dry field samples and split to around 2 oz (50 to 60 g).
2) Wet sieve this sample with demineralized water through a 230-mesh sieve (4 ϕ or 0.0625 mm) to separate the mud fraction.
3) Retain the mud/water fraction that passes through the sieve for hydrometer or pipette analysis if mud grain size information is required. If only percent of mud size is required, the mud/water mix can be put in a vacuum pump with residue placed on a 0.4 x 10^{-5} in^2 filter, dried, weighed and compared with original sample weight.
4) Carbonate percent can be determined by dissolving sand size fraction in a 20% solution of hydrochloric acid (HCl). The difference between the pre- and post-weight gives the percentage of calcium carbonate ($CaCO_3$).
5) Dry and sieve the sand fraction using the method described in Folk (1980). A sonic sifter is used at CERC's Coastal Geology Unit (Underwood, 1988) for size analysis. The sonic sifter has the speed of a settling tube but uses standard mesh sieves, and results are readily comparable to analyses using other sieving techniques.
6) It is recommended that 1/2 or 1/4 ϕ interval sieves (Table 1) be used for sand suitability analysis. Use of the method of moments for calculating sediment statistics (see Friedman and Sanders, 1978) incorporates all size fraction weight percents in the calculation and provides more accurate results. Older graphical techniques (Folk, 1980) only use a few data points and are not as accurate in calculation of sediment statistics.
7) Sediment mean and sorting (standard deviation) are the most important statistical values

and can be used in sand suitability analyses such as fill factor and renourishment factor calculations (SPM, 1984).

Table 1. Various sediment size classification methods in common use.

UNIFIED SOILS CLASSIFICATION		ASTM MESH	MM SIZE	PHI SIZE	WENTWORTH CLASSIFICATION	
			4096.00	-12.0		
			1024.00	-10.0	BOULDER	
			256.00	-8.0		
COBBLE			128.00	-7.0		G
			107.64	-6.75	COBBLE	
			90.51	-6.5		
			76.00	-6.25		
			64.00	-6.0		R
			58.82	-5.75		
COARSE GRAVEL			45.26	-5.5		
			38.00	-5.25		
			32.00	-5.0		A
			26.91	-4.75		
			22.63	-4.5		
			19.00	-4.25	PEBBLE	
			16.00	-4.0		V
			13.45	-3.75		
FINE GRAVEL			11.31	-3.5		
			9.51	-3.25		
		2.5	8.00	-3.0		E
		3	6.73	-2.75		
		3.5	5.66	-2.5		
		4	4.76	-2.25		
		5	4.00	-2.0		L
	Coarse	6	3.36	-1.75		
		7	2.85	-1.5	GRANULE	
		8	2.35	-1.25		
S		10	2.00	-1.0		
		12	1.68	-0.75	Very Coarse	
		14	1.41	-0.5		
		16	1.19	-0.25		
A	Medium	18	1.00	0.0		S
		20	0.84	0.25		
		25	0.71	0.5	Coarse	
		30	0.59	0.75		
N		35	0.50	1.0		A
		40	0.42	1.25		
		45	0.35	1.5	Medium	
		50	0.30	1.75		
D		60	0.25	2.0		N
		70	0.210	2.25		
	Fine	80	0.177	2.5	Fine	
		100	0.149	2.75		
		120	0.125	3.0		D
		140	0.105	3.25	Very Fine	
		170	0.088	3.5		
		200	0.074	3.75		
		230	0.0625	4.0		
		270	0.053	4.25		
		325	0.044	4.5		
SILT		400	0.037	4.75	SILT	
			0.031	5.0		M
			0.0156	6.0		
			0.0078	7.0		
			0.0039	8.0		
			0.0020	9.0		U
			0.00098	10.0	CLAY	
CLAY			0.00049	11.0		
			0.00024	12.0		
			0.00012	13.0	COLLOID	D
			0.00006	14.0		

Composite Sediments: Combining samples from across the beach can reduce the naturally high variability in spatial grain size distributions on beaches (Hobson, 1977). These composite samples are created by either physically combining several samples before sieving, or by mathematically combining the individual sample weights to create a new composite sample on which statistical values can be calculated and sediment distribution curves generated. Samples collected along profile sub-environments can be combined into composite groups of similar depositional energy levels and processes as seen in Figure 4.

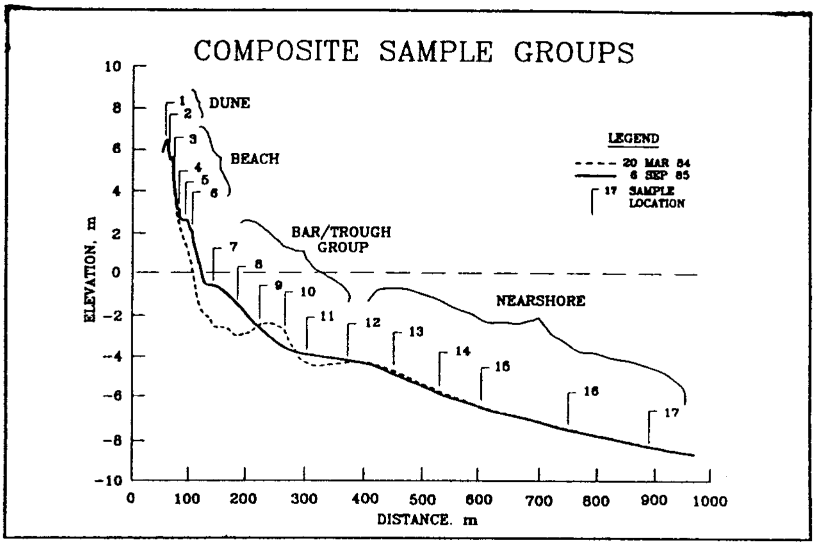

Figure 4. Composite sediment sample groups across a profile at the Field Research Facility, based on similarities in individual samples and depositional processes (Stauble, in press a).

The most usable composites were found to be the intertidal and subaerial beach samples, in the area of fill placement. After comparing several composite groups, Stauble and Hoel (1986) found that a composite containing the MHW, MT and MLW, gave the best representation of the native beach. Post-fill studies found that the intertidal sand composites showed resorting of fill material, while nearshore sample composite sediment distributions changed little over time. This suggests that active-sorting and sediment transport occurs on the active beach face and bar area and nearshore area sands remain unaffected by influx of fill material (other than the fine well-sorted fractions found on the native nearshore area of the beach).

Seasonal Variability: There can be a wide variability in grain size distribution on a native beach between winter high wave periods and summer fair weather periods. This variability can be a problem in choosing a representative native beach. The winter grain size distribution usually will be coarser and more poorly sorted than the summer distribution (due to the higher frequency of storms in the winter). The concept of the seasonal beach cycle is based on the frequency of storm-induced erosion and fair weather accretion. Extreme events, such as hurricanes that occur in the summer or early fall, as well as mild winters with few extratropical storm events, may cause perturbations on the seasonal cycle. A sampling strategy to characterize the seasonal variability should take into account the recent local storm climate. An example of seasonal sediment distribution variability was measured at Sebastian Inlet, FL (Stauble, et al., 1987). Due to environmental concerns, fill containing 20 % or more of finer than 2.75 ϕ (0.149 mm) material could not be used. Seasonal grain size sampling found that the summer intertidal composite native beach contained more than the allowed 20% fines. The winter intertidal composite was coarser as expected and contained less than 5% fines. A composite grain size distribution of the borrow area (the flood tidal delta of the inlet) fell between winter and summer native distributions. A follow up monitoring sampling showed that the fill was resorted and became finer but still was within the native beach fine component (Figure 5). Using seasonal sampling can help to determine the range of sediment size variability on the native beach and allow for calculation of the suitability of borrow material. See the SPM (1984) for fill factor and renourishment factor calculation techniques.

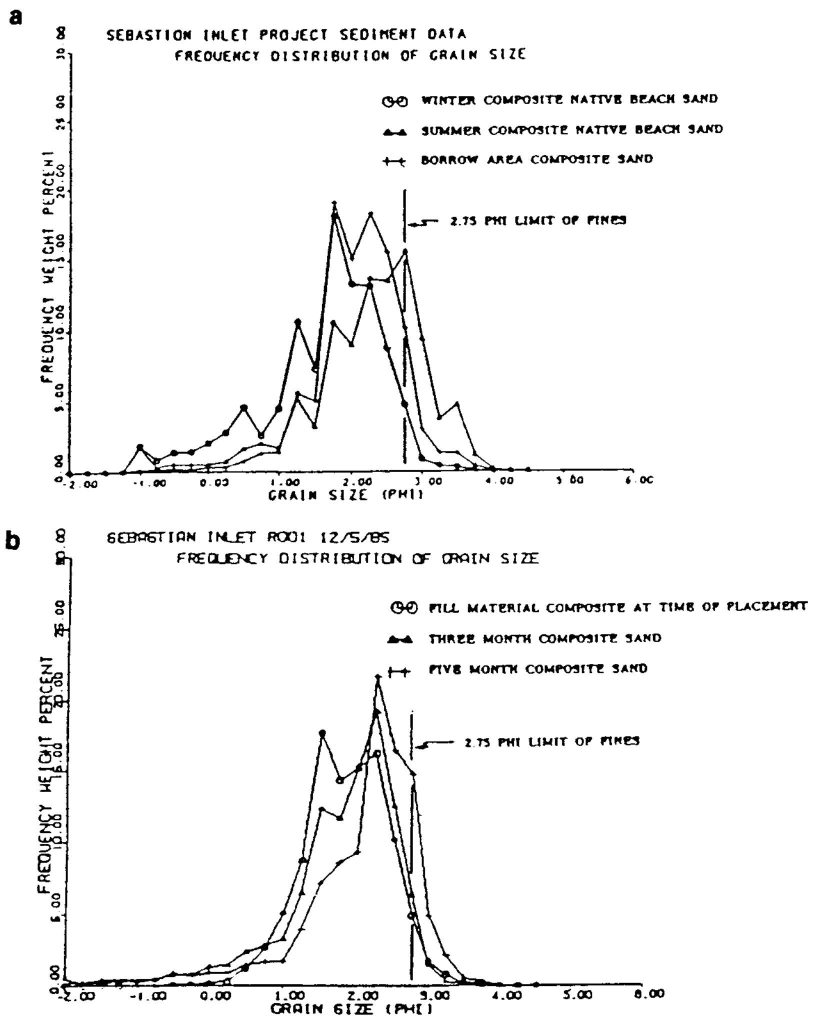

Figure 5. a) Comparison of summer and winter intertidal composite native beach sand with borrow area composite grain size distributions and b) comparison of fill sorting three and five months after placement (Stauble et al., 1987).

PROFILE DATA: Beach profile surveys also are important in characterization of the native beach. Cross-shore and along-shore variations are needed to identify morphology (ie. dunes vs seawalls, position of the berm crest, foreshore slope, bar and trough position and closure depth). These components are needed to calculate the volume of fill needed to provide desired storm protection and recreation.

Field Surveys: Location of beach profiles within the project is dependent on project length and variability in beach morphology, erosion control structures and funding availability. The cross-shore length of profiles should be from some recoverable benchmark well landward of storm erosion out to the depth of closure. The profile should start in an upland area that will have some reasonable chance of being stable through time. It is important that profiles reach closure depth to account for all of the active profile. Many projects in the past have only had wading depth profiles and much of the fill resorting, as well as bar migration, occurred seaward of the end of the profile and therefore was not documented. The land portion of the profile usually is taken with standard survey instrumentation. It is suggested that the

offshore portion of the profile be collected using the sled technique (Clausner, Birkemeier and Clark, 1986). The survey should be taken as close to low tide as possible to have the largest dry working area.

Closure Depth: It is important to know the area of active sediment transport on the native beach to accurately determine volumes required for beach nourishment. The distance to closure will aid in determining seaward extent of sediment movement. Closure at the seaward end of the profile is where there is no change in elevation between two successive profile surveys (SPM, 1984). Methods for closure depth determination are provided in the SPM (1984) and by Birkemeier (1985). Anders and Hansen (1990) found that closure depth varied annually at Ocean City, MD, depending on wave conditions. Higher wave conditions moved closure depth in an offshore direction, while during lower wave conditions closure depth moved toward the shore. They suggest that closure depth should be chosen on the anticipated wave conditions during project life. Extreme events may move the closure depth seaward of this point, but determination of an average closure depth will be adequate for project design purposes.

Seasonal Profile Envelope: Winter erosional beach profiles can be characterized as having concave foreshore areas and a well developed bar/trough in the nearshore. During fair weather summer conditions the bar moves landward and welds onto the foreshore producing a wider berm, with a lower bar/flatter trough. Again the profile response to the seasonal cycle is a function of storm frequency and intensity. When trying to determine the extent of the profile envelope, data of sufficient record length to cover at least one year or longer should be used. The profile envelope of the sediment study at the FRF is shown in Figure **4**, with the characteristic winter bar profile and summer berm profile. If core sampling will be used as described above, the depth of the active profile and core length can be determined by comparison of depth of erosional and accretional changes.

Design Templates: Once the closure depth and active profile envelope have been determined, an equilibrium profile can be chosen to best represent the project area. This existing equilibrium profile is then translated seaward as suggested by Hansen and Lillycrop (1988) to provide a realistic distribution of the fill volume. Recent profile studies to closure depth of beach fill performance at Ocean City, MD (Stauble, in press b) and Myrtle Beach, S.C. (Stauble et al., 1990) have shown that storms remove fill from the subaerial placement area, but transport the sand to the nearshore area. Most of the existing pre-storm fill material can be accounted for in the post-storm profile envelope and is not lost from the system.

SUMMARY: Guidance has been suggested on the proper techniques to sample and analyze data on the native beach prior to design of a beach nourishment project. Composite sediment grain size distributions of the active portion of the profile where the fill is to be placed give the best picture of native sand characteristics. Both cross-shore and along-shore variability need to be addressed to provide the data for assessing fill suitability. The seasonal profile envelope and depth of closure need to be determined for characterizing the active zone of the native beach. Calculation of the required fill volumes to provide the level of storm protection desired can then be performed with a reasonable degree of accuracy.

ADDITIONAL INFORMATION: For additional information on techniques to assess native beach characteristics contact Dr. Donald K, Stauble, Coastal Geology Unit, CERC at (601) 634-2056.

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